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Cost and Operational Effectiveness Analysis: Expectations of Customers and Suppliers and the Resources Required to Meet Them

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FOREWORD

This report presents a revision and expansion of a portion of NAWCWPNS TM 7484 *Issues Affecting the Integration and Coordination of Analysis at the Naval Air Warfare Center Weapons Division* of October 1993. That portion of TM 7484 this report focuses upon concerns the customers of analysis, their expectations for analysis and the resources required to meet those expectations. The identification of customers of analysis and a preliminary evaluation of their expectations were addressed in TM 7484 because an understanding of these elements is considered prerequisite to defining the analysis process and performing quality analysis.

Analysis customers, customer expectations, and the resources required to meet those expectations are featured here not only because they form a proper base from which to define and assess the analysis process. They also provide a base on which program managers (i.e., the customers of analysis) can define and justify the products they want and analysts (i.e., the suppliers of analysis) can justify the time and expense they must incur to supply the analysis products—and meet the customer's expectations. Thus, the impetus for this report is the belief that the better analysis customers and suppliers understand their roles and expectations i.e., the firmer the foundation upon which an analysis is planned and executed, the better the resulting analysis.

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(U) It seems reasonable to assume that the expectations of the program manager should be met as a Cost and Operational Effectiveness Analysis (COEA) is produced. But it is important to recognize in an analysis as complex as most COEAs, there is actually more than one type of customer. Probably the second most important "customer" is the analyst synthesizing the COEA from vast quantities and sources of data, involving many types of tools, processes, and people. This report begins with the analyst's fundamental expectation that any analysis, in particular any COEA, will be done with the rigor and integrity inherent in the scientific method. It then addresses the expectations the program manager has for a COEA that correspond to those of the analyst and others that may not: especially the program manager's expectations stemming from a need to meet budget and schedule constraints.

(U) Upon examination of the expectations of the program manager and the analyst, the conclusion is reached that the program manager's expectations include the analyst's plus those imposed by schedule and budget. The expectations for quality COEAs developed from this review of program manager and analyst needs are:

1. Consistent (Repeatable, Methodological Integrity)
2. Accurate (Accredited Models and Data; Trained and Experienced Analysts and Administrators)
3. Robust, comprehensive results
4. Documented results
5. Affordable
6. Timely
7. Accessible raw data and results

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8. Appropriate use of analysis resources
9. Simple in concept and approach (understandable)
10. Minimum administrative burden.

(U) These ten expectations are addressed in detail, particularly the practical requirements for meeting the expectation. The hardware (including the associated resources of facilities and ranges), software, procedures, and personnel required to meet the expectation are identified.

CONTENTS

EXECUTIVE SUMMARY

It seems reasonable to assume that the customer of a Cost and Operational Effectiveness Analysis (COEA) is a program manager. Thus it seems reasonable that the expectations of the program manager are those that should be met as a COEA is produced. But in an analysis as complex as most COEAs, it is important to recognize that there is more than one type of customer. Probably the most important other customer is the analyst who actually synthesizes the COEA from vast quantities and sources of data, drawing upon many types of tools, processes, and people. Regardless of whether or not the analyst is a customer or a supplier, the ultimate goal of both the program manager and analyst is the same: to support the acquisition of the best system to do the job. However, they do have different expectations about the COEA.

The analyst's fundamental expectation is that any analysis will be conducted with the rigor and integrity inherent in the scientific method. Many expectations the program manager has for a COEA comply with those held by the analyst, but other expectations, especially those stemming from the need to meet budget and schedule constraints, may not.

Upon examination of the expectations of the program manager and the analyst, the conclusion is reached that the program manager's expectations include the analyst's plus those imposed by schedule and budget. The expectations for quality COEAs developed from this review of program manager and analyst needs are:

1. Consistent (Repeatable, Methodological Integrity)
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5. Affordable
6. Timely
7. Accessible raw data and results
8. Appropriate use of analysis resources
9. Simple in concept and approach (understandable)
10. Minimum administrative burden.

As these ten expectations are considered in detail, the practical requirements for meeting the expectation are addressed. In particular, the hardware (including the associated resources of facilities and ranges), software, procedures, and personnel required to meet the expectation are identified.

INTRODUCTION

This document is a guide for program managers ("customers") as they seek to know what to expect when tasked to produce a Cost and Operational Effectiveness Analysis (COEA) (or for that matter, any kind of analysis), for their program. These expectations are developed from first principles and are summarized along with the resources required to meet them in the Appendix in Table A-1.

This document is also a guide for analysts to remind them that, although they are usually considered the "supplier" as opposed to the "customer" of analysis, they necessarily have expectations too. This guide provides customers and suppliers of analysis an understanding of the importance of various expectations, the interrelationship between customer/supplier expectations, and the cost of those expectations in terms of the resources required to meet and exceed them.

The guide begins with a brief description of customers and suppliers and an acknowledgment of their differences. The differences are important, but the goal of addressing the role of customer and supplier is to point out that despite their differences, they are obliged to work together to meet each others expectations and produce an effective analysis. In part, this is because both customer and supplier must respond to expectations over which they may have little control, namely the expectations of the bureaucracy as expressed in the documents that stipulate the contents of a COEA. Special attention is given to the expectations of this bureaucratic "customer" at the close of the "Customer Expectations" section.

THE ROLES OF CUSTOMERS AND SUPPLIERS

The customers using analysis in the form of assessments in the weapons acquisition process include a wide variety of officials at all levels of the defense establishment. The Department of Defense (DOD) Defense Acquisition Guidelines of February 1991, and in particular, DOD 5000.2 Part 14, list many of the administrators who use assessments to decide how and when weapon system proposals move through the phases of the acquisition cycle (References 1, 2 and 3). These administrators may be considered the primary customers of assessments; they include such officials as the Secretary of Defense (SECDEF), and deputy and assistant secretaries, the service secretaries, the Chiefs of Staff for the Air Force and Army and their staffs, the Chief of Naval Operations (CNO) and his staff (OPNAV), and the commanders of the systems commands and associated Program Executive Officers (PEOs), program managers (PMAs in NAVAIR) and Competency managers on the NAVAIR TEAM, e.g., Warfare Analysis (4.10), Cost Analysis (4.2), and Survivability (4.1.8).

Most officials involved in acquiring weapon systems find themselves in the role of both customer and supplier. Their roles are seldom exclusive or "pure." For example, the program office considered to be the *customer* by the field activities performing a given analysis may very well be the *supplier* of analysis to the office of an assistant secretary. This role reversal is a normal part of the flow of responsibility in an organization such as DOD. The role of "customer" is not fixed. This fact forces us to recognize that the identification of customer expectations involves an awareness of a considerable range of customer needs and preferences.

The breadth of the range of customers ultimately includes all administrators and scientists (analysts) involved in the analysis. This is true even at the level where individual analysts are running computer models to "produce" the raw analysis. Here, the analyst is both customer and supplier. Indeed, the analyst is a supplier of computer runs, but at the same time he or she is the customer of the input data necessary to make those computer runs.

Tension Between Customers And Suppliers

Often the program manager (administrator) of the weapon system moving through the acquisition process is considered the customer of any Cost and Operational Effectiveness Analysis (COEA) performed on the given weapon system. This means the COEA is paid for by the program manager and it is the program manager's expectations for a quality COEA that must be met. The analysts (scientists and engineers) running the models and performing the wide range of cost, survivability, effectiveness and mission analyses involved in producing a COEA are usually considered the suppliers of the COEA. These analysts strive to meet the expectations of their customer and at the same time maintain their integrity as professional scientists who hold rather stringent expectations of their own regarding a quality COEA.

Morse and Kimball in their classic text *Methods of Operations Research* note the potential for tension between the suppliers of analysis ("scientists") and the customers ("administrators") because the analyst may have a tendency to perform analysis to meet the standards of the scientific method whereas the customer expects quick assessments based on limited data. This tension is probably inevitable and it is no doubt a key reason customers (administrators and scientists) feel their expectations are not met. According to Morse and Kimball (Reference 4, p 10a)

> Scientist [analyst] and administrator [program manager] perform different functions and often must take opposite points of view. The scientist must always be skeptical and is often impatient at arbitrary decisions; the administrator must eventually make decisions which are in part arbitrary and is often impatient with skepticism. It takes a great deal of understanding and mutual trust for the two to work closely enough together to realize to the fullest the potentialities of the partnership.

Promoting the "great deal of understanding" Morse and Kimball mention here is the goal of this report. We need to know what the expectations of the customers and suppliers of analysis are, and we begin with the expectations of the supplier of COEAs, the scientist or analyst.

EXPECTATIONS FOR QUALITY COEAs

SCIENTIST EXPECTATIONS DERIVED FROM THE SCIENTIFIC METHOD

Analysis is, in general, considered part of the greater discipline of scientific research. As such, it is subject to the rules and regulations of the "scientific method," so it follows that some of the expectations the analyst/scientist has for quality include meeting the requirements of conscientious, methodical science.

One author identifies six steps to follow in exercising the scientific method, namely,

1. Make some general observations of a phenomenon.
2. Formulate a hypothesis about the phenomenon.
3. Develop a method to test that hypothesis.
4. Gather data to use in the test.
5. Test the hypothesis using the data.
6. Confirm or deny the hypothesis (Reference 5, p 38).

This list suggests that scientific research is a controlled process wherein tests are designed and conducted and observations are made to form conclusions. The validity of the conclusions depends on the ability of the scientist to repeat the observations, which in turn, depends on some accounting scheme, i.e., scientific method.

In practice, applying the scientific method to analysis projects involves conducting "good" experiments where the goodness of an experiment is based on meeting objective criteria such as logical design, repeatability, documentation, and control of intervening variables. For the scientist/analyst, meeting these criteria is not only an expectation associated with the practice of the scientific method, it is an essential part of the method.

Since meeting the scientist/analyst's expectations for good experiments is so critical, a more detailed list of criteria for determining whether an experiment or analysis is good is presented in Table 1. This list is based on D. R. Cox's *Planning of Experiments* (Reference 6). Along with the list of criteria is a list of the expectations that may be associated with those criteria.

SCIENTIST EXPECTATIONS REGARDING MODELS AND SIMULATIONS

Since models and simulations have become such a critical tool in the performance of assessments, meeting the expectations associated with their development, selection and use are also critical to the achievement of quality assessments. This critical link between quality models and quality assessments is recognized in the DOD 5000 series of directives (References 1, 2 and 3). The selection criteria for models suggested in that series is presented in Table 2 along with the expectations met when the given criteria are met.

A key guideline regarding the use of models from the Defense Acquisition Management Policies and Procedures deals with using appropriate models. According to the DOD manual,

> The complexity, scope, and output measures of mathematical models selected for the analysis should be appropriate to the system being evaluated. For example, a battalion size model need not be run to evaluate a new truck, and an antisubmarine warfare campaign model is not necessary for assessing the performance of new carrier onboard delivery systems. (Reference 2, p 4-E-3.)

TABLE 1. Criteria for Performing "Good" Experiments and the Expectations Associated With Them. (Much of this list is a paraphrase of a list found in Reference 6, p 13. Additional sources on the scientific method and experimental design are found in References 7 and 8.)

Characteristic	Expectation
1. Objects undergoing analysis (e.g., candidate attack aircraft systems) should be evaluated under the same conditions regardless of which tools (models) and procedures are used in the evaluation. To achieve repeatability or to enable independent analysts to conduct analysis simultaneously, the tools and procedures must be carefully controlled and the conditions (threat, environment, scenario, candidate system characteristics) clearly specified.	• Consistent (Repeatability, Methodological Integrity)
2. Random errors of estimation should be suitably small. This requirement is met by determining the sample population that must be measured to achieve the statistical precision desired and sampling no more or less than is required. In practice, this means that when a stochastic model is used, the number of runs made to measure a given effect—such as miss distance—should be determined by a statistical assessment of the desired precision.	• Appropriate Use of Analysis Resources
3. The analysis should address as wide a range of operational conditions as possible so that the conclusions drawn will be valid over a wide range of operational conditions.	• Robust and Comprehensive
4. The analysis approach should be simple and direct.	• Simple in Concept and Approach
5. A proper statistical analysis of the results should be possible without making artificial assumptions. Examples of artificial assumptions are smooth terrain, perfect communications, a clear electromagnetic environment, or the use of current tactics.	• Accurate • Robust
6. The analysis is not complete until it has been carefully reported.	• Documented

The importance of using quality (accurate, appropriate) data in whatever model is used is also clearly recognized in DOD 5000.2M. This guide stipulates:

> It is important to develop a validated database for the analysis. The data must be current, accurate, and technically and operationally validated by engineering assessments, technical tests, and operational tests. Additionally, current tactical and employment doctrine must be reflected in the database. (Reference 3, p 8-7.)

Here the expectation to be met is for accuracy based on the use of resources (data) that have been validated.

TABLE 2. Selection Criteria For Models and Simulations From DOD 5000, and the Expectations Associated With Them. (Reference 3, p 8-7.)

Selection criteria	Expectation
1. Like weapon systems, models are rarely entirely "good" or "bad." They are suitable or unsuitable for particular purposes.	• Appropriate Use of Analysis Resources
2. Models should help eliminate personal bias and preference. So be cautious when using models that include a "operator-in-the-loop."	• Accurate • Appropriate Use of Analysis Resources • Robust and Comprehensive
3. A great number of models already are available in almost every mission area. Consider them before attempting to build new ones.	• Appropriate Use of Analysis Resources • Timely Assessments
4. Keep the model simple. Often a simple mathematical equation can project the performance you are seeking to display.	• Simple in Concept and Approach
5. Be sure to test the model to see if it describes the base case well. Generally, we know more about the base case, the existing system, than we do about the alternatives. If the model does not "predict" what we know the existing system can do, it is not likely that its other predictions will be sound.	• Accurate • Robust and Comprehensive
6. Use several models. If different models yield similar results, one might gain confidence that the estimates are reasonable.	• Consistent (Repeatability, Methodological Integrity) • Appropriate Use of Analysis Resources

TABLE 2. (Contd.)

Selection criteria	Expectation
7. Run a "common sense" test. Are the results plausible? Are they within reasonable bounds?	• Simple in Concept And Approach
8. Evaluate the quality of the environmental simulation and the environmental limitation evaluation. For systems using sensors with a known vulnerability to adverse environmental conditions, for instance, does the model adequately incorporate the adverse effects of the environmental conditions during the simulation?	• Robust and Comprehensive

In addition to these guidelines for selecting models and data, the analyst and program manager) have expectations regarding the way the models and data are used. In particular, both analyst and program manager must recognize that the primary goal of a COEA is a valid, fair comparison; a comparison treating all candidates impartially; a comparison meeting expectations for methodological integrity and consistency. In their *Cost and Operational Effectiveness (COEA) Guide* (Reference 9, p 53), the Air Force Material Command stresses this critical aspect of the use of models by noting that:

> As much as possible, the analyst should take advantage of what a statistician would term "matched pairs" comparison. For example, if two similar aircraft are to be compared for cost and effectiveness in a particular mission, both aircraft should be evaluated with the same cost and the same operational effectiveness models. It is tempting, but often misleading, to use established, accepted, validated databases peculiar to the individual competitors, particularly for off-the-shelf buys.

Here again, tension may arise between the analyst striving for statistical validity and the program manager wanting to take advantage of good data that has already been paid for and that is available now. This brings us to a closer examination of some more of the expectations the program manager or administrator brings to the COEA.

ADMINISTRATOR (PROGRAM MANAGER) EXPECTATIONS

Time Related Expectations

Among other things, administrators (including those whom we in the weapons acquisition business call program managers) expect good science to be practiced in the performance of the analysis they request. This means that, in theory, the analyst who conducts analysis to the standards established for good science will be meeting some of the administrator's expectations. In practice, time limitations imposed on the analysis erode this theoretical compatibility. Time, or more accurately the lack thereof, inevitably introduces a tension between the exhaustive research often implied by the term "good science" and the responsiveness required when addressing pressing operational problems. As Morse and Kimball note:

> An important difference between operations research [e.g. mission effectiveness analysis] and other scientific work is the sense of *urgency* involved. In this field a preliminary analysis based on incomplete data may often be much more valuable than a more thorough study using

> adequate data, simply because the crucial decisions cannot wait on the slower study but must be based on the preliminary analysis. The worker [analyst] cannot afford to scorn superficial work, for wars (and, ofttimes, industry) do not wait for exhaustive study (although the exhaustive study should be made to back up the preliminary work). (Reference 4, p 10a.)

It seems one major new expectation the administrator/program manager has for the accomplishment of a COEA is to produce the analysis in a specified amount of time. The time factor puts pressure on the scientist/analyst to relax many, if not all, the criteria for good analysis presented above, thus reciprocal tension arises.

Related to the time constraint is the inevitable constraint on funds available for performing a given COEA. The prudent scientist/analyst expects resources of all kinds to be used in "cost-effective" ways as analysis is performed, but the demanding task of policing a COEA budget falls to the program manager. This means the program manager has a very high expectation that the COEA will be done within budget constraints; that indeed, it will be affordable.

Repeatability Requires Access

Another job that falls more to the administrators of COEAs than to the scientist/analyst performing the analysis, is relating the current COEA to previous COEAs of the same system (or to on-going, as well as past COEAs, of similar systems). The need to make such comparisons and even rebuild former COEAs is addressed in DOD 5000.2M in the section addressing cost analysis (Reference 3, p 15-3). According to the manual,

> The purpose of the documentation of cost estimates is to provide sufficient information about the way the estimates were produced so that Cost Analysis Improvement Group analysts could, provided *access* to the databases employed, reproduce the estimates. The means by which each part of the estimate was produced must be fully explained. [Emphasis added.]

This guidance suggests first that the program manager should expect thorough documentation of the COEA, but the key point to be emphasized here is that other administrators and analysts involved with the COEA–in this case, those in the Cost Analysis Improvement Group–need *access* to the databases employed in performing the COEA. What this means is that the requirement for repeatability addressed as an expectation associated with the scientific method is not simply a hollow academic requirement. COEAs are routinely repeated and such repetition is most effective when the raw data as well as the final results of previous efforts are quickly accessible in forms that can be clearly understood and used.

Expectations Stemming From COEA Evaluation Criteria

In addition to the expectations of timeliness, affordability and accessibility, program managers develop more expectations as they follow the guidelines in DOD 5000.2M for reviewing or evaluating the quality of a COEA. According to this guide, "There is no formal checklist for reviewing a cost and operational effectiveness analysis" (Reference 3, pp. 8-13 and 8-14), but the manual does provide a list of questions for evaluating COEAs; a list that reveals more of the expectations of the program manager. The list is presented in Table 3 as a key to determining other expectations program managers may have regarding quality COEAs.

TABLE 3. Questions For Evaluating the Quality of COEAs and the Customer Expectations Inferred From Them (Reference 3, pp. 8-13 - 8-14).

Evaluation question from DOD 5000.2M of 1991	Expectation
1. What are the problems, deficiencies, and opportunities being addressed? Are these symptoms of more basic concerns?	• Simple in Concept and Approach (Understandable)
2. Is the context (i.e., threat, scenario, environment) consistent with the Defense Planning Guidance? Has a spectrum of threats been considered? Have Allied forces been considered in appropriate detail?	• Consistent • Robust and Comprehensive
3. Have assumptions and constraints been identified explicitly? Are they reasonable? How would changes in them affect the results?	• Documented • Robust and Comprehensive
4. Have all reasonable alternatives been considered?	• Robust and Comprehensive
5. Were multiple measures of effectiveness used? Do they relate to the performance thresholds and objectives established for the system? To overall improvements in capabilities?	• Consistent • Robust and Comprehensive • Appropriate Use of Analysis Resources
6. Have all relevant costs been displayed? Has the Cost Analysis Improvement Group reviewed the cost estimates?	• Robust and Comprehensive • Accurate
7. Are the models clearly identified? Are they appropriate to the system being evaluated? Are the input parameters defined explicitly in the documentation? Can the results be replicated?	• Accurate • Consistent (Repeatability) • Documented
8. Has the database for the cost and operational effectiveness analysis been validated through engineering analyses or tests?	• Accurate • Documented
9. Does the analysis present all costs and measures of effectiveness for all alternatives? Have equal-cost or equal-effectiveness alternatives been examined?	• Robust and Comprehensive • Accurate
10. Are the criteria used for assessing alternatives identified explicitly? Are they meaningful? Consistent with higher order objectives? Intuitively acceptable or, if not, adequately explained?	• Documented • Simple in Concept and Approach, (Understandable) • Consistent
11. Do the results look reasonable? Is it clear from the analysis why the effectiveness measures came out as they did?	• Simple in Concept and Approach (Understandable)
12. Were sensitivity analyses conducted showing how changes in technical performance affect military utility, cost, and/or schedule? Do the results suggest reasonable ranges or thresholds for performance and cost?"	• Robust and Comprehensive • Simple in Concept and Approach (Understandable)

Program Managers Expectations Of Models And Simulations

In the assessment of expectations that administrators might have for COEAs, a set of "points" developed by the Director, Operational Test and Evaluation (OT&E) has been reviewed. This list of points is aimed at the use of modeling and simulation in support of OT&E, and, as such, it seems to be oriented more toward the expectations of program managers than analysts. (Note: The expectations of scientists/analysts regarding models and simulations are presented in Table 2.) The Director, OT&E, emphasizes the need for confidence. The Director's points are listed in Table 4 with the customer expectations associated with achieving the desired confidence.

TABLE 4. Set of Points Provided by the Director, OT&E, For Establishing Confidence in Models and Simulations. Also listed are the customer expectations associated with achieving the desired confidence. (Reference 10, pp. 6 and 7.)

Point	Expectation
Confidence in the model, based on a sound, coherent, systematic process used in development; sound model management structure, including configuration management; model descriptions, including usage, strengths and weaknesses, past history, adequate documentation; thorough description of verification and validation efforts; threat representation and usage; and thorough descriptions of accreditation efforts.	• Consistent (Repeatability, Methodological Integrity) • Accurate • Robust and Comprehensive • Documented
Confidence in the M/S [Modeling and Simulation] team. M/S practitioners must be experienced with the simulation being used and the system being simulated. That part of the team tasked with establishing the confidence in the model must be independent of the developers and users of the model or simulation.	• Accurate • Consistent (Repeatability, Methodological Integrity)
Confidence in M/S methodology and use, based on applicability or appropriateness to address requirements and issues under consideration, adequately described methodology and assumptions, certified and documented input data (including scenarios).	• Simple in Concept and Approach • Documented
Confidence in M/S results: M/S results should be consistent with actual field test results when the M/S input data are representative of actual field test conditions. Further, M/S results should be consistent with other M/S results when their input data are comparable. Any M/S results that appear counter-intuitive must be fully investigated in order to determine whether or not the results are in error or if the results actually reflect some new insight not previously anticipated. M/S results must include a description of related OT&E field tests, apparent inconsistencies, and any available resolution of issues identified.	• Accurate • Robust and Comprehensive • Documented • Consistent (Repeatability, Methodological Integrity)
Confidence in M/S results can be enhanced by comparison to other data, e.g., actual test results, other models, or historical data.	• Accessible • Documented • Consistent (Repeatability, Methodological Integrity)

Bureaucratic Expectations

Bureaucratic expectations are a special set of expectations usually presented as written requirements to which the program manager must respond; they are "imposed" or "specified" expectations. Perhaps they are more accurately categorized as the expectations of the decision makers at the Acquisition Review Board level.

Examples of these requirements begin with expectations of the purpose for the COEA. According to Reference 2, p 4-E-1 and 4-E-2, the COEA is performed for three reasons. These are:

> "1. . . . by illuminating the relative advantages and disadvantages of the alternatives being considered and showing the sensitivity of each alternative to possible changes in key assumptions (e.g., the threat) or variables (e.g., selected performance capabilities). Accordingly, the analysis takes the form of a problem of choice. The cost and operational effectiveness analysis should aid decision makers in judging whether or not any of the proposed alternatives to the current program (i.e., the status quo) offer sufficient military benefit to be worth the cost.
>
> 2. . . . by early identification and discussion of reasonable alternatives among decision makers and staffs at all levels.
>
> 3. . . . by providing the analytical underpinning or rational for decisions on a program. Accordingly, the analysis shall provide a historical record of the alternatives considered at each milestone decision point."

These goals are directly linked to the decision maker's expectations for accurate, robust, comprehensive, well documented analysis that is simple enough in concept and approach to be used to communicate the judgments made in selecting a particular weapon system.

Additionally, as Reference 2 points out,

> "A cost and operational effectiveness analysis will typically draw on several sub-analyses. These include analysis of mission needs, the threat and U.S. capabilities, the interrelationship of systems, the contribution of multirole systems, measures of effectiveness, costs, and cost effectiveness comparisons."

Here the point is made that the decision maker expects the COEA to be consistent throughout the process of coordinating and integrating various types of analysis. Furthermore, the decision maker expects the analysis to be robust and comprehensive enough to justify the decision in the broadest context of decision alternatives.

This foundation of expectations is further refined and expanded in Reference 2, where ultimately, a very detailed list of specified expectations is presented. A summary of these expectations is presented in Table 5 along with the general expectations implied in meeting the specified expectation.

TABLE 5. Specified Expectations Delineated in the Acquisition Guidelines for Performing COEAs (DOD 5000.2M Reference 2) And The General Expectations Implied in Meeting Them.

Specified Expectation (Page Numbers Are From DOD 5000.2M, Reference 2)	General Expectation
A comprehensive test and evaluation program is an integral factor in analyzing operational effectiveness . . . [p 8-1]	• Robust and Comprehensive
...establish the level at which the main analysis will be performed.... Whatever level is chosen, a check should be made of the implications for outcomes expected at the next higher organizational level. In many cases it will be necessary to consider results at several higher levels. [p 8-2]	• Robust and Comprehensive • Appropriate Use Of Analysis Resources • Consistent (Repeatable, Methodological Integrity)
The scenarios should include a set based on situations that conform to the scenarios in the Defense Planning Guidance.... The time period selected for the study should be of sufficient length to measure effects on mission capabilities once a system has been deployed in significant number[s]. [p 8-2]	• Consistent (Repeatable, Methodological Integrity) • Robust and Comprehensive
The threat should be analyzed in sufficient detail to identify , with a reasonable degree of assurance, the conditions that might exist when employing the new U.S. system.... Develop a range of plausible threats, to allow for the uncertainty inherent in threat projections. [p 8-3]	• Accurate • Robust and Comprehensive
Explore the implications of constraints on the threat. Ensure that a worldwide allocation of key threat forces underlies the specification of threat elements that would be engaged by the U.S. system. Consider logistics, personnel, and infrastructure factors that might affect the nominal performance of enemy weapons systems. [p 8-3]	• Accurate • Robust and Comprehensive
Evaluate explicitly the potential contribution of Allied forces. Describe Allied concepts of operation, projected force structures, and capabilities. [p 8-3]	• Accurate • Robust and Comprehensive
Evaluate terrain, weather, ocean or other pertinent environmental parameters. For atmospheric conditions, the analysis should be supported by meteorological data describing both normal and reasonably expected adverse weather conditions under which the system would be expected to operate. [pp 8-3, 8-4]	• Accurate • Robust and Comprehensive
For each threat environment there should also be expected mission capabilities. [p 8-4]	• Robust and Comprehensive
A good analysis embraces a solid statement and analysis of the organizational and operational plan for each alternative. These plans describe the way in which forces and equipment would be arranged and employed in battle. They address both doctrine and tactics in explaining how a system would be used to accomplish national objectives. [p 8-4]	• Consistent (Repeatable, Methodological Integrity) • Robust and Comprehensive
When structuring the set of alternatives, consider both current systems and improved versions, along with systems in development by the other Services or Allies and conceptual systems not yet on the drawing board. [p 8-5]	• Robust and Comprehensive

TABLE 5. (Contd.)

Specified Expectation (Page Numbers Are From DOD 5000.2M, Reference 2)	General Expectation
Where possible, include alternatives in which doctrine and tactics, rather than just hardware, are varied, since organizational and operational plans can change. Consider including alternatives with potential to mitigate significant, environmentally driven, performance limitations. [p 8-5]	• Robust and Comprehensive
It is important to develop a validated database for the analysis. The data must be current, accurate, and technically and operationally validated by engineering assessments, technical tests, and operational tests. Additionally, current tactical and employment doctrine must be reflected in the database. [p 8-7]	• Consistent (Repeatable, Methodological Integrity) • Accurate (Accredited Models and Data; Trained and Experienced Analysts and Administrators) • Documented
Cost estimates are as important as operational effectiveness measures in the analysis. Decision makers must combine cost considerations with assessments of operational effectiveness and potential constraints (e.g., timeliness, political considerations) in weighing alternatives. [p 8-8]	• Consistent (Repeatable, Methodological Integrity) • Accurate (Accredited Models and Data; Trained and Experienced Analysts and Administrators)
The analysis must address the system quantity for which a decision is being sought. The acquisition objective, if different, can be treated as an excursion. Quantity ranges are acceptable if the planned buy is within the specified range, is specifically addressed, and assumes a reasonable procurement schedule. [p 8-8]	• Accessible Raw Data and Results • Robust and Comprehensive
Estimates can be developed using a variety of techniques. There are three general approaches. 1. *Parametric methods* relate cost to parameters that specify a system within a class of systems, such as, weight and maximum speed for fighter aircraft. 2. In *estimating by analogy* one adjusts the known costs of existing systems similar to the one in question to arrive at cost projections. 3. *Engineering*, or *bottoms-up* estimates are made by pricing each component of a system. [p 8-8]	• Robust and Comprehensive • Simple In Concept and Approach • Appropriate Use of Analysis Resources
The cost input to the analysis must be validated at the sane level as the requirements document the analysis supports. Validation should identify the weaknesses, or "soft areas," in the cost estimates. [p 8-8]	• Consistent (Repeatable, Methodological Integrity) • Accurate (Accredited Models and Data; Trained and Experienced Analysts and Administrators) • Documented
The results of each sensitivity analysis must be documented. [p 8-9]	• Documented
Cost estimates take into account advanced development and engineering development. [p 8-9]	• Robust and Comprehensive • Accessible Raw Data and Results

TABLE 5. (Contd.)

Specified Expectation (Page Numbers Are From DOD 5000.2M, Reference 2)	General Expectation
Sensitivity analyses show explicitly how military utility is affected by changes in system capability. They shown how system characteristics (size, weight, etc.) drive performance, and how performance affects military utility or effectiveness. Parameters should be varied individually where it is reasonable to do so. The uncertainty inherent in estimating parameters and in determining their impact should be displayed explicitly. [p 8-10]	• Accurate (Accredited Models and Data; Trained and Experienced Analysts and Administrators) • Robust and Comprehensive • Documented
Compare equal-cost or equal-effectiveness alternatives. [p 8-11]	• Consistent (Repeatable, Methodological Integrity)
Show the absolute values of measures. Make the facts available and visible. Display the measures of cost and effectiveness for each alternative. [p 8-11]	• Accessible Raw Data and Results • Documented • Simple In Concept and Approach

Managing The Administrative Burden

One final expectation program managers have in their role as administrator of a COEA is for the COEA to be performed with as light an administrative burden as possible. Administrative burden includes the work involved with developing AirTasks, forming Integrated Product Teams, monitoring tasks and reviewing products, as well as the wide range of adjudication and budgetary decisions associated with COEAs. Adjudication decisions include deciding whether to use models or data that are not validated or accredited; deciding whether to fund a hardware upgrade in order to use the latest version of a model; deciding whether to exclude a particular threat because the existing models do not include it and deciding to negotiate another contract for analytical support because the existing in-house supplier is over committed or lacks the resources to address particular assessment requirements.

COMBINING THE EXPECTATIONS OF CUSTOMERS AND SUPPLIERS

Since the distinction between scientist (the supplier of analysis) and administrator (the customer) is really not definitive and their ultimate goal is the same, namely, supporting the acquisition of the best system to do the job, it can be argued that the expectations of an enlightened administrator derive from an intuitive appreciation of good science with explicit recognition of the demands of a schedule and a budget. So the administrator's expectations intrinsically include the scientist's expectations tempered with expectations imposed by schedule and budget. The following list of expectations is based on the preceding discussion of scientist and administrator needs. It is oriented to the administrator's goal: to encourage and promote the practice of good science while meeting production deadlines. Expect a quality COEA to be:

1. Consistent (repeatable, methodological integrity)
2. Accurate (accredited models and data; trained and experienced analysts and administrators)
3. Robust, (comprehensive results)
4. Well documented
5. Affordable
6. Timely
7. Accessible
8. Appropriate in the use of analysis resources
9. Simple in concept and approach (understandable)
10. Produced with minimal administrative burden.

RESOURCES REQUIRED TO MEET EXPECTATIONS

As these ten expectations are considered in detail, the practical requirements for meeting the expectation are addressed. In particular, the hardware (including the associated resources of facilities and ranges), software, procedures, and personnel required to meet the expectation are identified.

CONSISTENCY

Definition

Consistency can address two aspects of an assessment, namely the external consistency of the results of one assessment with other related assessments and the internal consistency of the models, databases, and procedures used to produce a given assessment. External consistency is usually addressed in terms of "repeatability" while internal consistency may be considered in terms of "methodological integrity."

Repeatability

Repeatability—probably the most useful surrogate for external consistency—is the fruit of internal consistency. An assessment is said to be repeatable or consistent when two independent researchers using essentially the same tools and procedures and working under the same environmental conditions are able to make the same observations; within the bounds of the statistical variability determined for the observations. Repeatability also addresses the situation where at a later time the same researcher conducts the same assessment and makes the same observations.

Repeatability is achieved through consistent, disciplined use of all the resources involved in the research and the disciplined accounting for all environmental factors that may influence the research. In addition, this disciplined use of resources involves ensuring that all tools used in the research are calibrated to certified standards; the research is conducted under carefully controlled and monitored conditions designed to limit the influence of intervening variables, and meticulous records are kept of the calibration history of tools and the results of environmental monitoring, as well as the values assigned to the variables under assessment, and the observations made.

Methodological Integrity

Meeting the expectation for internal consistency involves meeting the customer's need to be assured the criteria used to select tools, databases, hardware and procedures were applied uniformly throughout the entire analysis process. This internal consistency is the key to using assessments in conjunction with other analysis and in supporting the repeatability and external consistency of the assessment.

Consistency Means Credibility

The significance of consistency in the research arena is that it is the primary criterion used to determine the credibility of any conclusions drawn based on the research. Thus, the credibility of the research depends on the consistent application of the discipline of the scientific method throughout the research, and it is this same constancy of application that customers expect of assessments performed in support of the acquisition process. Customers must be assured analysts are consistent in the approach they take throughout the assessment; in the way they select databases; in the way they select and use models; in the way they employ supporting analysts; in the way they report their results; and in the level of internal review to which assessments are subjected.

There are numerous techniques for meeting and exceeding the expectation for consistency. These techniques involve the way hardware, software, procedures, and people are employed in the assessment process.

Hardware To Achieve Consistency

The most obvious way to achieve consistency in the use of hardware is to limit or carefully control the types and quantities of hardware used. Since assessments often involve the use of computers (and associated software) to model weapon systems, a very direct way to achieve consistency in the assessment process is to use a single computer and operating system. If such a direct approach is not possible, then every effort should be made to minimize the number of computer types and operating systems used in the analysis. In any event, the analyst should establish a set of criteria by which computer types and operating systems are selected and those criteria should be consistently applied throughout the analysis process.

Software To Achieve Consistency

As with computer hardware, the most direct approach of using software to achieve consistency in assessments is to limit or carefully control the software used. In the simplest case, this involves using the same model and the same database throughout the assessment. Currently, the state-of-the-art in modeling software does not support a single model that can address all aspects of a mission-effectiveness analysis for a complex weapon system. However, with the improvements projected for both hardware and software, a single model architecture that allows for the integration of multiple models may soon be available.

Procedures, Processes, And Methodologies To Achieve Consistency

Along with the judicious use of hardware and software, the use of various procedural devices is likely to promote consistency and the associated repeatability in assessments. The procedure of applying configuration management to control the software and hardware involved in analysis is critical to reproducing the particular configuration of hardware and software employed in making an assessment, and thus, a key to reproducing the assessment.

One of the most effective and commonly used procedures for achieving consistency and supporting reproducibility is the careful documentation of all aspects of the assessment. NAWCWPNS has developed a hierarchy of documentation guides

(References 11 and 12) that can be used to report on all aspects of assessments. Documents prepared in accordance with these guides must pass strict standards of formatting and review and should provide all the information needed to reproduce a test or assessment.

Personnel Issues Affecting Consistency

Finally, meeting the expectation for consistency involves a thorough understanding on the part of both administrators and analysts of the key role played by people in achieving consistent results. Both administrators and analysts should be trained in the fundamentals of the scientific method and the design of experiments. Analysts should be trained in the use of particular models and databases they use and the hardware associated with their use. They should be familiar with the local analysis process, as well as the fundamentals of the weapon system acquisition process. Administrators should be thoroughly trained in the weapon systems acquisition process and the fundamentals of the analysis process. Administrators and analysts leading the assessment effort should be experienced.

A summary of the resources associated with meeting and exceeding the expectation of consistency is presented in Table 6.

TABLE 6. Means (Resources) for Meeting and Exceeding Expectations for Consistency in Analysis.

Means (resources required) to meet and exceed expectation of consistency			
Hardware	Software	Procedure, process, methodology	Personnel
Limit types and quantities of hardware used Minimize types of computers and operating systems	Same model Same model version Same data Minimize models and databases Configuration management software Model integrating architecture	Configuration management in accordance with military standards Department/Center review of assessment tasks and products Apply documentation standards to models, databases, and analysis products Assessment process	Analysts trained in use of models, databases, and computers; local analysis process; fundamentals of weapon system acquisition Administrators trained in weapon system acquisition process; fundamentals of analysis Training in the scientific method and design of experiments

ACCURACY

Definition

The most accurate assessment of a weapon system involves measuring the effectiveness of the actual system in the combat environments for which it is designed.

Under such circumstances the system is used by field personnel against an active threat. Duplicating these conditions is the goal of the Operational Test and Evaluation (OPEVAL) required of all new acquisitions. Along with OPEVAL assessments is the Live Fire Test and Evaluation (LFT&E) process designed to evaluate actual hardware in the presence of a carefully controlled threat.

As a weapon system moves through the phases of the acquisition process, the degree to which it can be accurately assessed changes. Initially it is impossible to evaluate the hardware against actual threats because there is no hardware and the threat may be no more than an intelligence projection. Under these conditions, simulations and models are the appropriate tools for assessing the proposed weapon system.

Hardware To Achieve Accuracy

Running detailed engineering models, hardware-in-the-loop models, operator-in-the-loop models, and handling large databases and model integration requires high-capacity, high-speed computers. It requires computers that can be linked with hardware in the laboratory or in the field, operators in the laboratory or in the field, and facilities where multidimensional analysis may be performed (e.g., digital computer modeling along with hardware-in-the-loop simulations).

Procedures, Processes, And Methodologies To Achieve Accuracy

To achieve accuracy when using models to perform analysis, the models and associated databases must accurately represent the objects under evaluation, e.g., the threat missile system and the aircraft system modeled in a survivability assessment, as well as the environment in which the objects are expected to operate. Models and databases are said to meet these conditions when they have been "verified" and "validated." Verification involves testing models to determine if the mathematical algorithms used to represent the weapon system, the environmental system, and the threat system really do model these systems over the range of input data considered appropriate for the model. Verifying a model is accomplished by running a test case for which the outputs have been calculated and confirmed using previously verified models, proven subroutines, or "hand" calculations. The results of this run are compared to the confirmed results and the model is verified to be correct if it produces the same result as the proven techniques. Since models are often complex—involving thousands of lines of computer code and hundreds of mathematical algorithms—the key to verification is developing and using test cases that exercise the algorithms over the entire range for which they are designed. Furthermore, test cases must be subjected to the same configuration control as any other software to ensure new model versions can be compared to their predecessors.

Validating a model involves comparing the output of the model to empirical data. The empirical data to which the model results are compared may be developed in laboratory tests, field tests, the exploitation of hardware, or possibly from actual combat. In any event, for these data to be comparable to the model output, the object undergoing the field test must resemble the object being modeled. This means validation is usually limited for models of new systems and models are seldom validated for the full-range of conditions under which the weapon system might be used. Regardless of these operational limits to validation, the customer expects assessment results to reflect actual-test and field-use results as accurately as possible.

Additional procedures include the review of model results by technical experts associated with the kind of modeling performed, and procedures for analysts to perform quality checks on the data they are using and producing.

Software to Achieve Accuracy

Given a model that can be verified and validated, achieving accuracy in modeling a complex weapon system in the full-spectrum environment in which it may be used implies the need for software that links models to hardware; provides for operator-in-the-loop assessments; provides for detailed modeling, efficient modeling, and modeling that minimizes the need for operator monitoring or the production and handling of intermediate results. The concept of a model integrating architecture, mentioned earlier, is a response to these software needs. It addresses the need for a full range of modeling from detailed "emulative" models to the less detailed many-on-many mission-effectiveness models. Such an architecture also addresses the need for efficiency in handling data within and between models, hardware, operators, and databases.

Personnel Issues Affecting Accuracy

Analysts involved in producing accurate assessments should be trained and experienced in the operation of the models and data they use. Where they are responsible for the detailed assessment of weapon system components, the analyst should be familiar with the weapon system under evaluation and with the design and operation of the component. Administrators and analysts should be trained in the performance of integrated assessments, including the tasks involved with coordinating hardware, field tests, facilities, operators, and models.

A summary of the resources associated with meeting and exceeding the expectation of accuracy is presented in Table 7.

TABLE 7. Means (Resources) for Meeting and Exceeding Expectations for Accuracy in Analysis.

Means (resources required) to meet and exceed expectation of accuracy			
Hardware	Software	Procedure, process, methodology	Personnel
High capacity High speed Hardware-in-the-loop Operator-in-the-loop Special facilities Networked hardware, operators, facilities Exploited hardware	Emulation quality software Minimize data handling Software to link hardware, facilities, and operators Model integrating architecture	VV&A Standard test cases Analysts and supervisors perform quality checks Analysis reviewed by technical experts	Analysts trained in specific types and components of weapon systems Training in performing integrated, complex assessments Training in the use of all analytical tools

ROBUST ASSESSMENTS

Definition

Robust assessments are developed from analysis that is insensitive to reasonable variations in the characteristics of the weapon system, threat, environment, and any other conditions pertinent to the evaluation. Assessments are, and should be, subjected to penetrating criticism that inevitably includes questions regarding the effectiveness of the candidate system with a range of characteristics against a range of threats in a range of scenarios.

Providing assessments that address these questions involves a careful and thorough definition of the weapon system, the threat, and the environment. As the weapon system under evaluation is modeled in terms of critical performance characteristics, the analyst must not only justify the values assigned to these characteristics, but also the range over which the values are varied. Likewise, the analyst must evaluate the system against the widest possible range of threats in the widest possible range of environments using the widest possible range of tactics. Furthermore, a robust assessment will address performance in a comprehensive mission environment where the system is employed as part of a tactical unit interacting with other tactical units, the threat, and the natural environment.

Robust assessments are also the product of analytical diversity. An assessment is robust when the independent results of numerous types of evaluations lead to the same general conclusions. For example, this would be the case when the results of an analysis performed with a digital computer model were reinforced with the results of independent field or laboratory tests of the same or similar system.

Hardware To Achieve Robust Assessments

Hardware and facilities supporting robust assessments include the full spectrum of laboratory test equipment, digital computers, test ranges, hardware-in-the-loop and operator-in-the-loop equipment and facilities, communication and data links between hardware and facilities, exploited hardware, and the means for exploiting tests and hardware.

Software To Achieve Robust Assessments

Software supporting robust assessments includes models that accurately represent the critical characteristics of the system under evaluation, the threat, and the environment over as wide a range as possible. The models should also provide a comprehensive representation of the mission context in which the system is to be employed. This includes a complete representation of the natural and man-made environments and the command, control, communications, and intelligence (C^3I) network. Robust assessments also call for software that provides for interactive modeling using operators-in-the-loop and hardware-in-the-loop and the linking of models to field and laboratory tests.

Procedures, Processes, And Methodologies To Achieve Robust Assessments

Examples of the procedural techniques that may be employed to supply robust assessments are the development and use of plausible and comprehensive scenarios; interim reviews between analysis suppliers and customers; use of verified and validated models; coordination of field tests, laboratory tests and analysis runs; and the consolidation of current analysis and testing with related analysis previously performed.

Personnel Issues Affecting Robust Assessments

To use the hardware, software, and procedural techniques identified, analysts and administrators need to be trained in military operations in order to appreciate the variety of conditions in which weapon systems must operate. Participation in field exercises and activities such as environmental, reliability, and maintainability testing may also provide valuable insight into the mission environment. Analysts should also be cross-trained in the use of different types and levels of models and field and laboratory testing.

A summary of the resources associated with meeting and exceeding the expectation of robust assessments is presented in Table 8.

TABLE 8. Means (Resources) for Meeting and Exceeding Expectations for Robust Assessments.

Means (resources required) to meet and exceed expectation of robustness			
Hardware	Software	Procedure, process, methodology	Personnel
Hardware-in-the-loop Operator-in-the-loop Exploited hardware Range tests Field/fleet exercises Networked hardware	"Mission" analysis capability Model full spectrum of natural and man-made environment Model C^3I links Interactive	VV&A Standard scenarios Customer/supplier reviews Assessment process	Administrators and analysts trained in military operations Participation in field exercises Analysts cross-trained in weapon system types and tactics

WELL-DOCUMENTED RESULTS

Documentation Issues

An assessment is not complete until it has been documented and published in a timely manner. In effect, the assessment report is the tangible result of the assessment and it should be recognized and treated as such. Customers should carefully specify the kind of report or reports they expect and analysts, as good scientists, should be eager to supply a report that presents their findings clearly, provides the detail necessary to reproduce and confirm their results, and supports further assessments. A good summary of the issues that pertain to the expectations associated with documentation is provided in the Independent Cost Analysis section of DOD Manual 5000.2M (Reference 3, p 15-3). According to the manual,

> "The purpose of the documentation of cost estimates is to provide sufficient information about the way the estimates were produced so that Cost Analysis Improvement Group analysts could, provided access to the databases employed, reproduce the estimates. The means by which each part of the estimate was produced must be fully explained.
>
> Where a cost estimating relationship is used, its source must be cited completely, or the model and the set of data with which it was calibrated must be cited.
>
> Where judgment was used to adjust estimates made by analogy with other systems or components of systems, the backgrounds of those making the judgment must be given (e.g., are they cost analysts, engineers, vendor or Government employees?) as well as complete citations of the sources of the costs of the analogous system(s). Sources of the costs of each element in an engineering or 'grass roots' estimate must be cited completely."

Also of critical importance regarding the issue of documentation is the role it plays as ". . . a historical record of the alternatives considered at each milestone decision point" (Reference 2, p 4-E-1).

Hardware Supporting Documentation

The documenting of an assessment can be facilitated by the availability of hardware such as personal computers, portable (lap-top) computers, high-resolution printers and plotters, and other computer peripherals for displaying results such as scanners and video-to-digital converters. Other than hardware dedicated to documentation, consideration should be given to computer workstations or main frames that can host quality word-processing software.

Software Supporting Documentation

High-quality documentation often requires a combination of word processing, spread sheet, presentation, computer-aided design (CAD), and database software. In addition, models with such built-in software such as statistical, documentation, and graphics post-processors support the documentation process. Since report formatting is a very demanding yet routine part of documentation, some kind of software package addressing local report-formatting requirements would likely enhance the documentation process.

Procedures, Processes, And Methodologies Supporting Documentation

Since documentation is the tangible result of an assessment, administrators at the local level should include it as an expected result in the analyst's performance plan. Administrators should be prepared to review or arrange for the review of documentation produced both in terms of clarity and technical accuracy. Analysts should be able to reference databases and models in their reports; this presents a requirement that databases and models be documented. A standard documentation format for assessments facilitates the documentation and review process, and a standard review process in turn establishes guidelines for documentation.

Personnel Issues Affecting Documentation

Well designed and executed assessments address documentation as an integral part of the assessment. In terms of training, this suggests the need for analysts and mid-level administrators to be competent in the design of experiments, and in the skills involved in data reduction and data presentation such as statistics and graphics. Analysts should be familiar with document formatting requirements and review processes. Administrators supervising analysts should be trained in performance planning and in reviewing documentation

A summary of the resources associated with meeting and exceeding the expectation of well documented assessments is presented in Table 9.

TABLE 9. Means (Resources) for Meeting and Exceeding Expectations for Well Documented Analysis.

Type of resources required to meet and exceed expectation of well documented analysis			
Hardware	Software	Procedure, process, methodology	Personnel
Personal computers Workstations with capacity for word processing and graphics	Word processing, spread sheet, and presentations software Word-processing software tailored to TP or TM format Graphics outputs Statistics post-processors Models with documentation post-processors	Document review Performance plans requiring documentation of analysis to meet expectations Standard documentation format Level of documentation linked to level of analysis Documented databases Documented software Assessment process that includes documentation	Analysts trained in statistics, documentation, design of experiments, and local and headquarters analysis review processes Administrators trained in documentation review and performance planning

AFFORDABILITY

Affordability Issues

Cost constraints limit the amount of analysis and testing included in an assessment, but they need not limit meeting and exceeding customer expectations for a quality assessment. Too often cost limitations are used as an excuse to completely ignore or at least dilute other expectations such as robustness or documentation. The object is to make quality assessments affordable by recognizing at the outset of the process that resources are limited and the assessment should be made in accordance with those limitations.

Hardware Promoting Affordability

Hardware contributes to the cost of assessments in two ways: first as an initial capital outlay, then as an item requiring maintenance and other overhead support. In addition to these costs, acquiring and using hardware involves paying and training operators and these costs should be considered in the acquisition and use of the hardware. Means for reducing these costs include limiting the amount of hardware needed for an assessment, sharing hardware with other assessment projects, acquiring hardware with low overhead expenses, and efficiently using the hardware.

Software Promoting Affordability

Software used in performing an assessment supports affordability when it enables analysts to perform their jobs quickly, allows for the efficient integration of supporting analysis such as field tests and hardware- or operator-in-the-loop assessments, and supports the documentation and configuration management tasks. Such software has the characteristics of ease of use (user friendly), efficient architecture, flexibility (i.e., software that can be used on different types of hardware and software that supports the assessment of more than a single aspect of an engagement), and low overhead in terms of licensing fees, upgrading, and training. Software that is verified, validated, and well documented supports affordability by relieving the user of these responsibilities in the course of performing the assessment. Of considerable aid to administrators when accounting for the cost of performing the assessment, would be a networked program management software package enabling them to track all analytical resources consumed. Likewise, analysts could use some form of accounting software to give them an up-to-the-minute status of all the cost-related parameters associated with their models. Such software would allow for the development of metrics to improve their models and analytical processes. Since many of these software characteristics match those set as goals for a model integrating architecture, it seems that such an architecture also promises a means for more affordable assessments.

Procedures, Processes, And Methodologies Promoting Affordability

Procedural steps for achieving affordability include optimizing hardware usage with such procedures as those that ensure the number of computer runs made for an analytical task is appropriate for the type of model being used, that ensure the fidelity of the model and data, and that clearly define the requirements for statistical reduction of the data. Procedures may also aid in optimizing and coordinating the number of suppliers involved in the assessment and in optimizing and coordinating the use of expensive resources such as sophisticated operator or hardware-in-the-loop assets, range time, laboratories, specialists, and field exercises.

Personnel Issues Affecting Affordability

Administrators and analysts need to be aware of how the various elements of assessments contribute to the cost of the assessment. This suggests a need for administrators and analysts to be familiar with the types of assets used to perform analysis and the costs associated with acquiring, using, and maintaining those assets. Both administrators and analysts need to be well trained and experienced in the practice of their respective disciplines.

A summary of the resources associated with meeting and exceeding the expectation of affordable assessments is presented in Table 10.

TABLE 10. Means (Resources) for Meeting and Exceeding Expectations for Affordable Analysis.

Means (resources required) to meet and exceed expectation of affordable analysis			
Hardware	Software	Procedure, process, methodology	Personnel
Low overhead Fast Networked hardware Reliable Short repair and/or maintenance time Supports multiple users	Low overhead Fast Flexible Program management software On-line, up-to-date management information system Budget presentation and analysis software	Minimize computer usage Optimize hardware-in-the-loop and/or interactive requirements Minimize number of suppliers "Tag along" arrangements with field tests	Administrators trained in the cost of owning and operating simulation and test capabilities Analysts trained in the proficient use and maintenance of their models Administrators and analysts certified in their disciplines

TIMELINESS

Timeliness Issues

When the effectiveness of a military force is linked more to the *quality* rather than the *quantity* of the weapon systems employed, the acquisition of new systems is driven by a need to employ new, effectiveness-enhancing technologies as soon as possible. The more a force depends on the qualitative superiority of its weapons to achieve superiority on the battlefield, the more critical is the time factor in weapons acquisition.

Since the effectiveness of the U.S. military does depend, in part, on weapon systems that are technically superior to those of potential adversaries, there is a constant need to infuse new technologies into the weapons systems employed by our forces. This demand for fresh technologies is a primary reason acquisition managers expect timeliness in the performance of assessments supporting the weapon-system acquisition process. Of course, there are other reasons to perform assessments quickly. These include the need to keep the cost of the assessment down and the need to perform assessments within the scheduling constraints associated with limited assets such as ranges, specialized facilities and laboratories, computers, and personnel. Furthermore, the performance of assessments must be coordinated with other customers and suppliers, maintenance cycles, training, and in the case of an asset such as a test range, even the weather. For all these reasons, time is a critical element of assessments.

Hardware Promoting Timeliness

Hardware designed to support timely assessments can be quickly set up for its assessment function, is easy to use, has minimal maintenance or other downtime requirements (high reliability, low failure rate, short repair time), operates in all-weather and laboratory conditions (for hardware exposed to such conditions), supports multiple users simultaneously, supports time-saving software, supports the automatic flow of data from other hardware, and performs its function quickly.

Software Promoting Timeliness

Software features supporting timely assessments include high speed (optimum architecture and languages); user friendliness; and automated links between databases, other models, hardware, documentation, and configuration management software. To support timely assessments, software should be verified, validated, and documented. To as great an extent as possible, software should be quickly and easily transportable (hardware independent) so analysts using various types of hardware can be using the same model simultaneously and data generated or stored on one type of hardware can be used with models loaded on other types of hardware. Again, many of these software features match those set as goals for a model integrating software architecture, so it seems such an architecture also has merit as a means to more timely assessments. To aid administrators in accounting for the time spent in performing the assessment, a networked program management software package would be helpful. In the same vein, analysts could use software to give them an up-to-the-minute accounting of all the time related parameters associated with their models. Such software would allow for the identification and alleviation of "bottle necks" in the models and analytical processes.

Procedures, Processes, And Methodologies Promoting Timeliness

Other means for meeting the expectation for timeliness in assessments include procedures that help optimize the number of suppliers involved in an assessment to minimize the total time involved. This kind of optimizing needs to occur at all levels of the assessment process and suggests that procedures for team building are a valuable way to make the process run quickly. Other procedural means supporting timeliness include procedures to minimize the number of runs associated with computer modeling and the number of trials associated with field or laboratory tests. Procedures may be useful in minimizing the reviews involved in the documentation aspect of the assessment, avoiding the delays associated with training, verification, and validation; ensuring analysts and administrators involved in the assessment are properly experienced and trained; and ensuring software and data are documented and configuration management is practiced. Procedures may also be useful in providing for the quality control of analysis at the level where it is performed, while it is being performed.

Personnel Issues Affecting Timeliness

In order to provide timely assessments, administrators should be experienced and well trained in the weapon system acquisition process and this includes skill in the use of program management software. Administrators and analysts should appreciate why time is such a critical factor in the acquisition of high-tech weapon systems for a military force dependent on qualitative superiority. They should be familiar with the hardware, software, and procedural means for reducing the time involved in making assessments.

Analysts should be experienced and well trained in the use of the particular tools associated with their parts of the assessment and they should be aware of the need to coordinate and expedite the flow of data throughout the assessment process. Analysts and administrators should be prepared to quickly form and operate as teams.

A summary of the resources associated with meeting and exceeding the expectation of timely assessments is presented in Table 11.

TABLE 11. Means (Resources) for Meeting and Exceeding Expectations for Timely Analysis.

Means (resources required) to meet and exceed expectation of timely analysis			
Hardware	Software	Procedure, process, methodology	Personnel
Fast (parallel, optical) User friendly Flexible Networked hardware Short repair and/or maintenance time Supports multiple users	Fast Optimum architecture Model integrating architecture Program management software On-line, up-to-date management information system	Minimize number of suppliers Minimize model runs Minimize reviews Provide quality control at analysis level Coordinated customer/ supplier interfaces Certified analysts	Administrators proficient in weapon systems acquisition Analysts proficient in analysis process

ACCESSIBILITY

Definition

Part of the weapon system acquisition process involves the development of a foundation of assessments that confirm each other and justify the continued development and ultimate fielding of a new weapon system. Such a foundation is necessary because circumstances surrounding the original operational requirement and statement of need for the weapon system may change as the acquisition proceeds. Thus, the acquisition manager is forced to not only justify the passage from one phase of development to another, but also to re-justify the need for the proposed system given changed circumstances. One means of supporting this justification and re-justification requirement has already been addressed, namely, the production of robust assessments; assessments that remain valid over a wide range of developmental and operational conditions. Regardless of whether or not an assessment is robust, any assessment is of little use to the acquisition manager involved in the justification or re-justification of the system if that assessment is not accessible. Thus, accessibility is critical to the support of the weapons acquisition process.

In addition to this demand for accessibility due to the nature of the acquisition process as an accumulation of analysis, there is the demand for accessibility stemming from the nature of assessments themselves as iterative or open-ended products. As a weapon system is refined and modified in the acquisition process, assessments can be refined to incorporate new levels of detail and the results of empirical evaluations. Model

verification, validation, and enhancement is occurring in parallel with the design of weapon system hardware, so even if the hardware changes little, the ability to model it may improve dramatically and warrant a reassessment of the system. Again, robust assessments made with accurate models of well-defined systems help keep the need for reassessments at a minimum, but for any reassessment to be effective the original assessment must be accessible.

Hardware Supporting Accessibility

With the flexible hardware available today, accessibility should not be a hardware problem. However, hardware can play an important role in facilitating access. Some ways to facilitate access are the acquisition and use of computers with a capacity for the storage and retrieval of the voluminous data generated in assessments. The hardware should also support networking, so stored data is accessible to multiple assessment suppliers and customers. Given the sensitivity of some data generated, the hardware should also support the control and monitoring of access to the data.

Software Supporting Accessibility

Software supports accessibility when it provides for the automated storage and cataloging of data as it is generated, when it provides for the automation and standardization of data labeling, when the models generating data have input and output interfaces that provide for direct linkage to data storage, when stored data is formatted for direct use by assessment models, and when the software supports complete and timely documentation of assessment results. Software that enhances accessibility should also be user friendly.

Procedures, Processes, And Methodologies Supporting Accessibility

The most direct way to provide accessibility to assessments is to ensure the assessment is completely documented, published, and distributed as soon as possible after the completion of the assessment. Although the generation of hard-copy documents has been made somewhat obsolete by the availability of magnetic and optical storage and dissemination, the principle of documenting as the key to accessibility remains. Procedures for documentation should ensure that preparation and review of documentation is conducted with accessibility requirements in mind. Accessibility should also be a critical design criterion in the development of models and databases.

Other procedures supporting accessibility are the use of documented software, configuration control of software, making resources available to develop and maintain libraries where data are stored and from which data are retrieved, providing for networking among assessment archives and data libraries, providing for the control and monitoring of access to the libraries, and the establishment of national centers (such as the Information Analysis Centers (IACs) for the collection and dissemination of models and databases. The "World Wide Web" also offers a vehicle for providing tremendous access to analysis provided appropriate limits to access can be achieved.

Personnel Issues Affecting Accessibility

Administrators and analysts need to appreciate the need for accessibility and the fact that documentation in its various forms is the primary means for achieving accessibility. They need to be trained in the development and use of on-line libraries and the utility of the IACs. Analysts and administrators should consider taking an active part in professional societies and user groups aimed at the development and dissemination of assessment techniques, the results of ongoing assessments, and development of specialized databases and models.

A summary of the resources associated with meeting and exceeding the expectation of accessibility is presented in Table 12.

TABLE 12. Means (Resources) for Meeting and Exceeding Expectations for Accessible Analysis.

Means (resources required) to meet and exceed expectation of accessible analysis			
Hardware	Software	Procedure, process, methodology	Personnel
High-volume, high-speed storage and retrieval Secure Networked hardware	User friendly Configuration management Models with post-processors for library functions Well defined I/O interfaces File servers World Wide Web access to models, data, briefings, program definition	Access to data libraries controlled and monitored Single library administration Standard file naming convention Resources dedicated to library development and maintenance	Administrators trained in use of on-line libraries Analysts trained in library development and maintenance

APPROPRIATE USE OF ANALYSIS RESOURCES

Issues Relating To The Use Of Appropriate Analysis Resources

The resources that may be employed in assessments of weapon systems are as complex as the weapon systems themselves. In fact, it may be argued that an assessment tool such as an instrumented range is as complex as the most complex system (or combination of systems) tested on that range. But in choosing the resources (tools, facilities, software) for a particular assessment, the primary selection criterion is simplicity—to select the least complex resource or set of resources that will support an assessment that unequivocally answers all the questions posed at the milestone review. Use of this selection criterion is based on the premise that the most revealing assessment is that which presents the clearest links between the stimulus to the system and the response of the system. Achieving these clear links requires the use of tools that provide an appropriate level and type of stimulation, measure the appropriate responses, and produce data that is easy to use and understand while the operation of the tools and

influence of those tools on the data is clearly understood. Tools that cloud the relationship between stimulus and response are tools that (1) produce unnecessary amounts or types of data; (2) produce data requiring unnecessary manipulation such as translating data produced in specialized formats or languages into standard formats and languages before it can be used; (3) have not been calibrated, validated, or verified; (4) require the use of inexplicable and subjective adjustment factors; or (5) produce data that is difficult to retrieve, preserve, or interpret.

Appropriate Hardware

The means to meet the expectation that appropriate analysis resources are used in an assessment include: providing a full spectrum of resources for use in the various levels and types of assessments; providing hardware that meets such design criteria as ease of use, low-maintenance, interoperability, and low-training requirements; providing hardware suited to software and peripherals; providing hardware (including facilities and ranges) that meets the environmental constraints imposed on testing; and providing hardware that can be linked to other hardware, software or databases to achieve flexibility in building up or down in complexity.

Appropriate Software

Software as a means of meeting expectations for the use of appropriate resources in assessments include: using software that has been validated and verified; coordinating the fidelity of models and databases; using software that is thoroughly documented; providing software that is user friendly; and providing software that is easily linked to other software and that can be run on various types of hardware designed to the architectural standards that allow for modular growth in complexity.

Appropriate Procedures, Processes, And Methodologies.

It seems the development and implementation of procedures has been one of the key ways to meet expectations for the appropriate use of resources in assessments. Some of these procedures are dissemination of model descriptions in catalogues and dissemination of information regarding test facilities, specialized hardware, and major exercises through catalogues and brochures; development of calendars that list upcoming tests; dedication of resources for the development, test, validation, verification, and maintenance of software; exchange tours for both administrators and analysts that encourage understanding and communication between supplier and customer; and the establishment of documentation requirements that address the need for a clear, understandable explanation of the use and impact of the resources used in the assessment. Other related means include the coordination of software development, maintenance, validation, verification, and dissemination through national and multiservice organizations such as the IACs, Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME), JTCG/AS, Electromagnetic Code Consortium (EMCC), and Joint Coordinating Group for Electronic Warfare (JCG-EW).

Personnel Issues Associated With The Appropriate Use Of Analysis Resources

To understand why care should be taken to use the least complex resources when making assessments, administrators and analysts need to be trained in the scientific method and the design of experiments. To know what resources are available to support assessments, both administrators and analysts need to be introduced to the full spectrum of resources, including a description of the fundamental workings of the resources and examples of the types of assessments for which the resource is appropriate. Finally, analysis suppliers as well as administrators need to be aware of the kinds of questions asked at program review milestones.

A summary of the resources associated with meeting and exceeding the expectation of appropriate use of analysis resources is presented in Table 13.

TABLE 13. Means (Resources) for Meeting and Exceeding Expectations Associated With The Appropriate Use Of Analysis Resources.

Means (resources required) to meet and exceed expectation of appropriate use of analysis resources			
Hardware	Software	Procedure, process, methodology	Personnel
Hardware suited to software Hardware use proportional to analysis problem Hardware, facilities, exercises sensitive to environmental constraints Networked hardware	State-of-the-art software Coordination of model and data fidelity Model integrating architecture Program management software	Catalogue of models Catalogue of facilities Calendar of exercises, tests, TECHEVALs, OPEVALs Dedicated resources for software development, testing, maintenance, validation, and verification Software documentation Coordination of software development through national, multiservice bodies (e.g., JTCG/AS, JTCG/ME, EMCC, IACs, JCG-EW)	Administrators and analysts trained in scientific method and design of experiments Administrators and analysts trained in full spectrum of analysis resources Analysts trained in the weapon system acquisition process and familiar with the questions asked at program milestone reviews Headquarters-to-field exchange tours Exchange tours for analysts

SIMPLICITY: SIMPLE IN CONCEPT AND APPROACH

Issues

For the same reason that tools used to support assessments should enable both customer and supplier to make the clearest links between the stimulus to which the proposed system is subjected and the response of the system, the entire assessment should be only as complex as necessary to provide answers to the questions asked at the milestone reviews. It is also important to recognize that the acquisition process itself is

based on the emergence of an operational system in stages beginning with theories and projections and ending with hardware. This staging is used to reduce the risks involved in development by controlling the introduction of complexity. E. B. Wilson (Reference 8, p 36), in his study of the design of experiments notes that,

> "...it is almost always desirable or even necessary to approach answers in stages, starting with the most idealized and simplified version possible. When this has been unraveled, more general cases can be attacked."

Furthermore, since assessments are made to address system behavior that is inevitably unpredictable, the assessment approach should be simple and flexible enough to allow for the investigation of unpredictable or unusual results as the assessment proceeds. But one of the most compelling arguments for simplicity in the design and execution of assessments stems from the need for the assessment to be understood. As Morse and Kimball (Reference 4, p 10) point out,

> "...it must be emphasized that the problem is not completed when the details of the operation are understood by the operations research worker alone. Since the purpose of the analysis is to provide the executive department with a basis for decision, the problem is successfully completed only when the executive department understands the essential parts of the conclusions of the analysis."

Hardware Promoting Simplicity

The conception and design of an assessment involves expectations for quality planning and management. These expectations are not as easy to meet with hardware as some of the other expectations addressed. It is likely that meeting the expectation for simplicity in the conception and approach of an assessment will include the use of hardware that is appropriate to the assessment task, but this alone does not guarantee that the assessment itself will be simple and clear in concept and approach. In general, hardware that supports management, planning, and the networking of administrators and analysts will be needed to provide the coordination of all the resources involved in an elegant assessment.

Software Promoting Simplicity

Software means for encouraging simplicity and clarity in the design and execution of assessments also focus on software that enhances program management and communications. Such software can provide the links between administrator and analyst, analyst and other analysts, and all assessment resources necessary for the coordination of the assessment task. It can also enable administrators and analysts to keep track of the resources being used in an assessment and provide the means of documenting and evaluating the relationships between resources. Of course, the use of well-designed software that is itself simple, clear, and matched to the analysis tasks involved are simple in concept and approach. Some of the characteristics of such software were addressed when the goal of meeting expectations for the use of appropriate resources in assessments were considered.

Procedures, Processes, And Methodologies Promoting Simplicity

Supplying an assessment that is simple and clear in conception and approach involves the use of procedures that support the availability of well-designed and proven hardware and software and well-trained and experienced administrators and analysts. But in addition to the rather strict application of procedures usually associated with model validation and verification and training, the achievement of simplicity and clarity involves the need for flexibility in procedures and the freedom to improvise and innovate as an assessment proceeds. In the course of performing an assessment, unexpected discoveries or the availability of new hardware such as an actual threat missile system may provide a means of greatly simplifying the assessment. Procedures should not inhibit the introduction of simplifying ideas and resources, but neither should they allow for the casual abandonment of an approach until the alternative is proven to merit consideration. The need to make judgments regarding the merit of approaches, data, tools, and other resources as an assessment is planned and executed suggests a requirement for procedures that allow for incremental and pilot assessments prior to making a major, full-scale assessment involving the commitment of substantial resources.

Personnel Issues Associated With Simplicity

Supplying assessments that are simple and clear in concept and approach, especially when one means of supplying such an assessment is to provide for flexibility and innovation, requires trust and cooperation between the planners and executors of the assessment. Such trust is encouraged when both administrators and analysts are confident of their own training and the availability of resources required for a quality assessment. It is also encouraged when suppliers understand and appreciate the needs of customers throughout the acquisition hierarchy, and when customers understand and appreciate the needs of assessment suppliers at all levels. Gaining such understanding involves the thorough and ongoing training of administrators and analysts in their respective fields and the cross-training of administrators in the field of analysis and analysts in the field of administration. Such cross-training could be accomplished with exchange tours between the offices of the administrators and analysts. Finally, the elegant design and execution of assessments calls for training of both administrators and analysts in the scientific method and design of experiments.

A summary of the resources associated with meeting and exceeding the expectation of simplicity in concept and approach is presented in Table 14.

TABLE 14. Means (Resources) for Meeting and Exceeding Expectations Associated with Simplicity in Concept and Approach.

Means (resources required) to meet and exceed expectation of simplicity in concept and approach			
Hardware	Software	Procedure, process, methodology	Personnel
Self contained Self sufficient Low overhead	User-friendly models Graphics Minimize models and	Minimize number of suppliers Analysis approach	Administrators and analysts trained in scientific method and

TABLE 14. (Contd.)

Hardware	Software	Procedure, process, methodology	Personnel
	model interfaces Program management software	scaled to problem Flexible analysis approach Pilot assessments Assessment process Verified and validated tools	design of experiments Cross-training between analysts Exchange tours between analysts and administrators

MINIMAL ADMINISTRATIVE BURDEN

Issues

Bureaucratic interfaces (AirTasks, Memoranda of Understanding (MOU), inter-Departmental tasking agreements), standards, licensing agreements, security requirements, travel, and contracting requirements are elements of the administrative burden associated with performing assessments as part of the weapon systems acquisition process. In general, administrative tasks do not contribute directly to the accomplishment of assessments, but they must be performed to acquire and maintain hardware and software, to implement and control procedures, and to pay and train personnel.

Hardware To Minimize The Administrative Burden

The most direct approach to minimizing the administrative burden is to limit the number of customers and suppliers involved in an assessment. In terms of hardware, this suggests limiting the types and quantities of computers used to model the candidate system. It means limiting the facilities associated with the assessment. To avoid travel and duplication of hardware and software, it may mean linking facilities and hardware with data networks or the development and use of teleconferencing centers.

Software To Minimize The Administrative Burden.

Software issues related to minimizing the administrative burden include limiting the types and quantities of models used in the assessment; using models that are pre-approved or "accredited" by the customer (so the tasks of validating, verifying or justifying the use of models during the assessment will be eliminated); using models written in common languages that can be compiled and run on a wide variety of computers; using models that have user-friendly input/output (I/O) interfaces that will allow for the direct linkage of model to model, or model to hardware; and the direct linkage to common databases. A model or model set with many of these characteristics is the goal of the model integrating architecture (previously mentioned as a means to meet the expectations of consistency and accuracy).

Procedures, Processes, And Methodologies Minimizing The Administrative Burden

Procedures that seem to offer promise as means to minimizing the administrative burden are: (1) identifying a single entry point for initiating assessments in the

assessment supplier's organization, (2) developing a "certificate" program for analysts so customers can be assured their assessment resources will not be consumed in the administrative tasks of training analysts and acquiring hardware, (3) developing standard forms for assessment AirTasks and MOUs, and (4) using a single process for the internal review of assessment products. Another key procedure for reducing administrative tasks is the requirement that all software be supported with complete and up-to-date documentation. Procedures such as department- or Center-level review of assessment tasks and products should also be considered as a means of encouraging coordination among assessment suppliers.

Personnel Issues Associated With Minimizing the Administrative Burden

To help relieve the administrative burden, administrators and analysts need to be trained in the weapon system acquisition process. Administrators need to appreciate the unavoidable and necessary administrative requirements involved in the ownership of complex facilities, secure computers, computer software, and the constant need to train analysts in the state-of-the-art of analysis and military technology. To the extent common databases and networked models are available, analysts need to be proficient in the use of such resources. Analysts and administrators need to respect the needs for a single-point-of-entry to assessment suppliers, or at least control the way customers interface with suppliers.

A summary of the resources associated with meeting and exceeding the expectation of minimal administrative burden is presented in Table 15.

TABLE 15. Means (Resources) for Meeting and Exceeding Expectation of Minimal Administrative Burden.

Means (resources required) to meet and exceed expectation of minimal administrative burden			
Hardware	Software	Procedure, process, methodology	Personnel
Minimize types and quantities of hardware Networked facilities and hardware Teleconferencing center	Single model Certified models Minimize types and quantities of models Model integrating architecture	Single analysis supplier Certified suppliers Minimize suppliers Control of entry points to analysis process Standard assessment AirTasks and MOUs Department/Center review of assessment tasks and products	Analysts trained in weapon systems acquisition Administrators familiar with capabilities of suppliers

SUMMARY OF PROGRAM MANAGER AND ANALYST EXPECTATIONS

This assessment of expectations has been undertaken to provide managers of COEAs and those performing the analysis involved in COEAs a guide for the decisions to be made when defining and performing a COEA. This guide supports the decision-making process by listing ten essential expectations program managers and analysts may have of a quality COEA. These expectations are, in effect, criteria by which the choices made during a COEA, (ranging from who should be included on the COEA "team" to which models and data should be used), may be justified. Applying these criteria effectively involves asking at each decision point whether or not the resulting activity will support a COEA that is:

1. Consistent (Repeatable, Methodological Integrity)
2. Accurate (Accredited Models and Data; Trained and Experienced Analysts and Administrators)
3. Robust, (comprehensive results)
4. Well documented
5. Affordable
6. Timely
7. Accessible
8. Appropriate in the use of analysis resources
9. Simple in concept and approach (understandable)
10. Produced with minimal administrative burden.

These ten expectations are distilled from several lists of expectations and measurement criteria, and the distillation process is presented in the body of this document. Whether or not there should be ten or twenty essential expectations, and whether or not the ten identified do, in fact, represent the essential expectations is of course open to criticism. In defense of the ten selected, they were developed using first principles presented in this report.

The point is, it is essential that program managers have confidence in the COEA for which they are responsible. They need to know it was performed to high analytical standards and the conclusions presented can be defended clearly and honestly. They need to know the resources they've spent on the COEA were necessary: that they were expended in a prudent and reasonable way. If the ten expectations addressed above are met, program managers can be confident they will have this knowledge.

Both analysts and program managers need to have a clear justification for the effort and resources they expend in performing a COEA. Analysts need to know what is expected of them by the COEA customer, and they need to be able to defend their expectations of what they consider quality analysis. They need to be able to negotiate with the customer over which expectations take priority as the COEA is performed. In particular, program managers and analysts need to be able to work with each other to resolve the inevitable tension arising between the customer's expectations for timely, inexpensive analysis and the analyst's professional stake in accurate, robust analysis.

There can be disagreement regarding priority of all the expectations, and their priority is likely to change from COEA to COEA. Hopefully, this guide defines the ten expectations completely enough so program managers and analysts have a sound base on which priority may be negotiated.

A summary of the expectations of assessment customers (program managers) and suppliers (analysts) and the means (resources) required to meet those expectations is presented in the Appendix.

APPENDIX

TABLE A-1. Expectations of Assessment Customers and Means (Resources) for Meeting and Exceeding the Expectations.

Expectation	Means (resources required) to meet and exceed expectation			
	Hardware	Software	Procedure, process, methodology	Personnel
Consistent	Limit types and quantities of hardware used Minimize types of computers and operating systems	Same model Same model version Same data Minimize models and databases Configuration management software Model integrating architecture	Configuration management in accordance with military standards Department/Center review of assessment tasks and products Apply documentation standards to models, databases, and analysis products Assessment process	Analysts trained in use of: models, databases, and computers; local analysis process; fundamentals of weapon system acquisition Administrators trained in weapon system acquisition process; fundamentals of analysis Training in the scientific method and design of experiments
Accurate	High capacity High speed Hardware-in-the-loop Operator-in-the-loop Special facilities Networked hardware, operators, facilities Exploited hardware	Emulation quality software Minimize data handling Software to link hardware, facilities, and operators Model integrating architecture	VV&A Standard test cases Analysts perform quality checks Analysis reviewed by technical experts	Analysts trained in specific types and components of weapon systems Training in performing integrated assessments Training in the use of all analytical tools
Robust	Hardware-in-the-loop Operator-in-the-loop Exploited hardware Range tests Field/fleet exercises Networked hardware	"Mission" analysis capability Model full spectrum of natural and man-made environment Model C^3I links Interactive	VV&A Standard scenarios Customer/supplier reviews Coordination between assessment suppliers Assessment process	Administrators and analysts trained in military operations Participation in field exercises Analysts cross-trained in weapon system types and tactics

TABLE A-1. (Contd.)

Expectation	Means (resources required) to meet and exceed expectation			
	Hardware	Software	Procedure, process, methodology	Personnel
Documented	Personal computers Workstations with capacity for word processing and graphics	Word processing, spread sheet, and presentations software Word-processing software tailored to TP or TM format Graphics outputs Statistics post-processors	Document review Performance plans requiring documentation of analysis to meet expectations Standard documentation format Level of documentation linked to level of analysis Documented databases Documented software Assessment process that includes documentation	Analysts trained in statistics, documentation, design of experiments, and local and headquarters analysis review processes Administrators trained in documentation review and performance planning
Affordable	Low overhead Fast Networked hardware Reliable Short repair and/or maintenance time Supports multiple users	Low overhead Fast Flexible Program management software On-line, up-to-date management information system Budget presentation and analysis software	Minimize computer usage Optimize hardware-in-the-loop and/or interactive requirements Minimize number of suppliers "Tag along" arrangements with field tests	Administrators trained in the cost of owning and operating simulation and test capabilities Analysts trained in the proficient use and maintenance of their models Administrators and analysts certified in their disciplines
Timely	Fast (parallel, optical) User friendly Flexible Networked hardware Short repair and/or maintenance time Supports multiple users	Fast Optimum architecture Model integrating architecture Program management software On-line, up-to-date management information system	Minimize number of suppliers Minimize model runs Minimize reviews Provide quality control at analysis level Coordinated customer/supplier interfaces Certified analysts	Administrators proficient in weapon systems acquisition Analysts proficient in analysis process
Accessible	High-volume, high-speed storage and retrieval Secure Networked hardware	User friendly Configuration management Models with post-processors for library functions Well defined I/O interfaces File server World Wide Web access to models, data, briefings, program definition	Access to data libraries controlled and monitored Single library administration Standard file naming convention Resources dedicated to library development and maintenance	Administrators trained in use of on-line libraries Analysts trained in library development and maintenance

TABLE A-1. (Contd.)

Expectation	Means (resources required) to meet and exceed expectation			
	Hardware	Software	Procedure, process, methodology	Personnel
Appropriate analysis resources	Hardware suited to software Hardware use proportional to analysis problem Hardware, facilities, exercises sensitive to environmental constraints Networked hardware	State-of-the-art software Coordination of model and data fidelity Model integrating architecture Program management software	Catalogue of models Catalogue of facilities Calendar of exercises, tests, TECHEVALs, OPEVALs, Dedicated resources for software development, testing, maintenance, validation, and verification Software documentation Coordination of software development through national, multiservice bodies (e.g., JTCG/AS, JTCG/ME, EMCC, IACs, JCG-EW	Administrators and analysts trained in scientific method and design of experiments Administrators and analysts trained in full spectrum of analysts resources Analysts trained in the weapon system acquisition process and familiar with the questions asked at program milestone reviews Headquarters-to-field exchange tours Exchange tours for analysts
Simple in concept and approach	Self contained Self sufficient Low overhead	User friendly Graphics Minimize models and model interfaces Program management software	Minimize number of suppliers Analysis approach scaled to problem Flexible analysis approach Pilot assessments Assessment process Verified and validated tools	Administrators and analysts trained in scientific method and design of experiments Cross training between analysts Exchange tours between analysts and administrators
Minimum administrative burden	Minimize types and quantities of hardware Networked facilities and hardware Teleconferencing center	Single model Certified models Minimize types and quantities of models Model integrating architecture	Single analysis supplier Certified suppliers Minimize suppliers Control of entry points to analysis process Standard assessment AirTasks and MOUs Department/Center review of assessment tasks and products	Analysts trained in weapon systems acquisition Administrators familiar with capabilities of suppliers

ACRONYMS

C^3I	command, control, communications, and intelligence
CAD	computer-aided design
CNO	Chief of Naval Operations
COEA	Cost and Operational Effectiveness Analysis
DOD	Department of Defense
EMCC	Electromagnetic Code Consortium
I/O	input/output
IACs	Information Analysis Centers
JCG-EW	Joint Coordinating Group for Electronic Warfare
JTCG/ME	Joint Technical Coordinating Group for Munitions Effectiveness
LFT&E	live fire test and evaluation
MOU	Memoranda of Understanding
M/S	modeling and simulation
NAWCWPNS	Naval Air Warfare Center Weapons Division
OPEVAL	operational test and evaluation
OPNAV	Office of the Chief of Naval Operations
OT&E	operational test and evaluation
PEO	program executive officers
PMA	Program Manager (in NAVAIR)
SECDEF	Secretary of Defense

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